GENDER DIFFERENCES IN MIRROR-TRACING TASK PERFORMANCE

A Thesis
Presented to
The Academic Faculty

by

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In Partial Fulfillment
of the Requirements for the Degree
Master of Science in the
School of Psychology

Georgia Institute of Technology
December 2011

GENDER DIFFERENCES IN MIRROR-TRACING TASK PERFORMANCE

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Date Approved: August 10, 2011

ACKNOWLEDGEMENTS

I would like to thank my advisor, Phillip L. Ackerman, for all of his help and advice throughout my thesis project. I would also like to thank my family, especially my husband, for always believing in me and supporting me. This has been a long journey and I am grateful for everyone's patience and understanding.

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SUMMARY

The purpose of this research is to examine the gender differences that exist when male and female participants complete the mirror-tracing task. This task was chosen because it requires both spatial and psychomotor abilities and is unusual in the sense that it has a far higher correlation with standard spatial ability measures than do most other psychomotor tests. This research focuses on gender differences in speed, accuracy, and practice effects. It also investigates two personality traits that correlate with performance on the task: introversion and anxiety. Data were collected from three studies: Experiment 2 of Ackerman & Cianciolo's (1999) study, Experiment 3 of Ackerman & Cianciolo's (2000) study, and Experiment 1 of Field's (1998) study. Significant improvement in task completion time was found for both males and females over 40 trials. Males completed the mirror-tracing task faster than females throughout all three assessment periods. However, the results showed females making significantly more errors than males only during initial assessment, not during intermediate or final assessment.

CHAPTER 1

HISTORY OF THE MIRROR-TRACING TASK

The mirror-tracing task was first implemented in 1920 by George S. Snoddy in an attempt to "obtain a complete genetic record of the act of learning at each stage of its development" (Snoddy, 1920, p.1). At that time, researchers were interested in understanding the methods behind learning (Snoddy, 1920). Of particular interest was the concept of "trial and error learning," which occurs when an animal (or human) associates a particular behavior with the consequences that behavior produces, thus if the behavior produces pleasant responses, the animal is likely to repeat the behavior (Snoddy, 1920).

Previous researchers believed that learning began with a trial and error process and ended with a 'controlled' and 'purposeful' procedure (Snoddy, 1920). However, according to Snoddy, no research had attempted to understand the intermediate links between these stages of learning (1920). In an attempt to fill this void in the research literature, Snoddy created the mirror-tracing task. He believed that this task would allow him to better understand each stage of learning because "it involved a certain degree of difficulty for the learner; that improvement in learning to trace this figure promised to be rapid and to be open to accurate objective measurement; and that the time required to make a single complete tracing of the figure promised to be sufficiently short" (Snoddy, 1920, p.1).

Although the mirror-tracing task was originally developed to study the processes behind learning, the task has been used in a variety of research domains to study many other variables including, psychomotor and spatial abilities (e.g., Ackerman & Cianciolo, 1999, 2000; Alexander, Packard, & Peterson, 2002; Petersik & Pantle, 1982), hemodynamic responses which concern blood circulation and regulation (Allen & Matthews, 1997), and the effects of diseases (e.g. cardiovascular and Alzheimer's) on mental/motor abilities (Harrell & Floyd, 2002; Rouleau, Salmon, &Vrbancic, 2002).

Description of the Task

The apparatus used to conduct the mirror-tracing task has evolved with technology; however the basic components of the task have remained the same. Before computers were available, the mirror-tracing task involved a metal or brass six-point star pattern that was mounted on glass or wood (see Figure 1). This created a path, in the form of a star, whose edges were made of metal/brass and whose base was made of glass/wood (Snoddy, 1920).

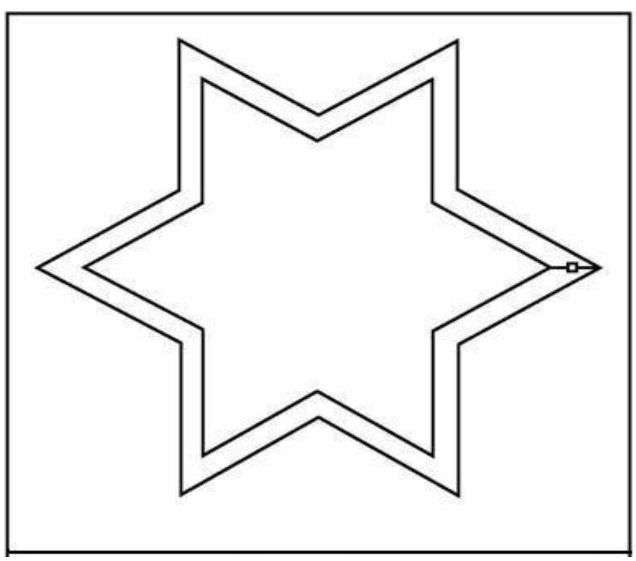

Figure 1. Star portion of the mirror-tracing task apparatus.

Participants were then asked to trace the star within the metal path; however, they were not allowed to look at their hand or the actual star. Instead, the participants were required to trace the path by looking at the reflection of the pattern in a mirror. Furthermore the participants were instructed to trace the pattern without touching the metal/brass borders of the star. To trace the design, participants were given a stylus that was made of brass or metal and resembled a regular lead pencil in size.

This task can now be completed through the use of touch screen computers. The same star pattern can be displayed on computer monitors and participants are able to trace the pattern with a TouchPen (or their finger). To implement the mirrored effect, participants trace the star pattern on one side of the screen and monitor their performance by watching their progress appear in mirrored line transformation within the target pattern on the other side of the computer screen (Ackerman & Cianciolo, 1999). However, this computerized version of the task differs from the original version in terms of lacking tactile feedback when the metal is touched.

Speed- Accuracy Tradeoff

No matter what apparatus is used, participants are asked to trace the star pattern as quickly as possible without going outside of the pattern (Snoddy, 1920). Task performance is based on the completion time and the number of errors made (Alexander et al., 2002). An error occurs if a participant makes contact with the metal edges of the pattern or draws outside of the lines on the paper. Because the participants are encouraged to complete the task quickly and with as few errors as possible, the participants are faced with a dilemma as to whether to focus on speed or number of errors. Some participants may choose to work quickly but make many errors, while other participants may choose to work slowly without making any errors. Choosing between these two types of strategies is often referred to as the speed verses accuracy trade-off.

Woodworth (1899) was one of the first authors to examine the speed-accuracy phenomenon; he claimed that a movement consists of two parts, an initial impulse followed by current control. Woodworth asked participants to make repetitive movements at 20 to 200 movements per minute. This experiment led Woodworth to note that errors increased as the rate of movements increased (1899). According to Woodworth, the reason that errors increase as speed increases is due to the efficiency of current control to negate any error that occurs at the initial impulse phase. In 1954, Fitts' Law was developed and based on Woodworth's research to explain the logarithmic relation between speed and accuracy (Kim et al., 1996).

Gender and Speed -Accuracy

In 1986, Lohman explained sex differences in mental rotation performance by investigating the effects of speed-accuracy tradeoff. He developed speed-accuracy tradeoff functions based on 1,200 mental rotation problems that were completed by 83 participants (30 male and 53 female). The results indicated that speed-accuracy functions differed significantly between males and females when the participants mentally rotated objects 90, 120, and 150 degrees. Females' speed-accuracy functions reached asymptote sooner than did males. Lohman concluded that this difference in speed-accuracy functions could explain why females seem to have slower rates on mental rotation (1986). Thus, sex differences in rate of rotation might be a consequence of sex differences in asymptotes of speed-accuracy functions (Lohman, 1986).

Furthermore, Quiroga, Hernandez, and Rubio (2007) researched gender differences in the speed-accuracy tradeoff while also looking at gender differences in cognitive styles. Within their study, participants (N=1652; 984 males and 668 females) completed both a spatial orientation and a general intelligence task. According to Quiroga et al. (2007), men took longer to complete the task (0.23 seconds more; d=.309) but also made fewer mistakes (*d*= -.811). Thus, women tended to favor response speed whereas men tended to favor response accuracy, at least on these tasks. Finally, Quiroga et al. (2007) concluded that sex differences in spatial tasks can be partly attributed to sex differences in the speed-accuracy tradeoff.

Gender Differences in Task

Although there is only a modest literature concerning the existence of gender differences in the mirror-tracing task, Ackerman and Cianciolo (1999) reported a male advantage for the task, when measuring completion time; however, they did not report any error data. The purpose of their research was to test the reliability and validity of computer-based psychomotor tests. One of the psychomotor tests within their battery was a computerized version of the mirror-tracing task. Ackerman & Cianciolo (1999) noted substantial gender differences in speed, as large as 1σ in mean differences, favoring males in all of the psychomotor tests, including the mirror-tracing task.

Conversely, other researchers have recorded faster completion times for female participants. Alexander, Packard, & Peterson (2002) assessed mirror-tracing performance within their study of gender differences and position effects on object location memory. Alexander et al. (2002) asked 17 males and 13 females to complete the mirror-tracing task and found that females were faster than males in the early trials of the task, $F\ (2, 26) = 5.95$, $p = 0.02$; however, both males and females made similar numbers of errors (Alexander et al., 2002). Allen & Matthews (1997) used the mirror-tracing task to measure hemodynamic responses in children and adolescents. Within their study, 159 children and adolescents completed the mirror-tracing task (78 males and 79 females). They reported that females completed more tracing patterns (20.4) than did males (13.7) within the given time; however, they also noted that younger girls were more likely to trace outside of the track than younger boys, but this difference in errors did not exist for the adolescent participants (Allen & Matthews, 1997). Thus, it seems that the literature on gender differences in completion time of the mirror-tracing task provides conflicting results; however, it also seems that no significant sex difference in the number of errors exists for adolescents and adults.

Abilities Used to Perform the Task

The spatial and psychomotor nature of the mirror-tracing task can be seen through the previous research that has used the task when assessing both spatial and psychomotor abilities (e.g., Ackerman & Cianciolo, 1999, 2000; Alexander, Packard, & Peterson, 2002; Petersik & Pantle, 1982). Therefore, the mirror-tracing task requires aspects of both spatial and psychomotor abilities. The next sections will provide thorough descriptions of both abilities and detail the spatial and psychomotor nature of the task.

CHAPTER 2

SPATIAL ABILITIES

Defining Spatial Ability

The concept of "spatial ability" is not easily defined. Generally spatial abilities entail visual problems or tasks that require individuals to estimate, predict, or judge the relationships among figures or objects in different contexts (Elliot & Smith, 1983). More specifically, spatial abilities have to do with individuals' abilities to search the visual field, apprehend forms, shapes, and positions of objects as visually perceived, form mental representations of those forms, shapes, and positions, and manipulate such representations mentally (Carroll, 1993).

Taxonomy of Spatial Abilities

The taxonomy of spatial abilities constructed by Lohman, Pellegrino, Alderton, & Regian (1987) was developed to help researchers classify spatial tests into spatial subdivisions. Lohman et al. proposed the existence of 10 distinct and significant subdivisions of spatial abilities. Although it is unnecessary to list and describe all 10 subdivisions within this text, it is important to point out that the mirror-tracing task is associated with two subdivisions of spatial ability: spatial orientation and spatial scanning. It qualifies as a test for spatial orientation because it requires subjects to determine how an object will appear when viewed from a new perspective due to the mirrored aspect of the task. It also meets the criteria for a test of spatial scanning because it requires both speed and accuracy in following an indicated route or path (i.e. the star pattered path).

Gender Differences in Spatial Abilities

One of the most widely discussed topics that is currently being researched concerning spatial ability deals with an existence, or lack of an existence, of sex differences in spatial abilities (Maccoby &Jacklin, 1974; Caplan, MacPherson, & Tobin, 1985). This highly debated topic has recently gained even more attention after Lawrence Summers (the recent President of Harvard University) made claims concerning the differences between men and women and their different levels of representation, especially in the faculties of science and mathematics fields (Summers, 2005). No clear agreement on the subject matter has been reached. For example, Maccoby and Jacklin (1974) contended that gender differences in spatial ability do exist, while Caplan et al. (1985) contended that any gender differences found are too small to be significant or consequential.

Arguments for Gender Differences in Spatial Ability

Many researchers believe that substantial sex differences in spatial abilities do exist (Voyer, Voyer, & Bryden, 1995; Maccoby & Jacklin, 1974). Most researchers have not been able to claim that gender differences in spatial abilities exist across the entire range of sub-factors of spatial abilities; however, Voyer et al. (1995) conducted a meta-analysis that reported an overall mean weighted *d* of 0.37 indicating that males outperform females on all subdivisions of spatial abilities. Therefore, according to Voyer et al. (1995) men would be superior at the mirror-tracing task which requires spatial orientation and scanning abilities. Other researchers have only been able to find sex differences in specific subdivisions of spatial ability. For example, Maccoby and Jacklin (1974) made claims of gender differences using only one sub-factor of spatial abilities.

They separated the field of spatial ability into two groups: non-visual and visual spatial abilities and then used the Embedded Figures Test to suggest that visual-spatial ability tests show sex differences favoring men. Thus, because the mirror-tracing task is visual in nature, Maccoby and Jacklin (1974) would suggest that men would perform better than women when completing the task.

Crawford et al. (1995) proposed that women are negatively influenced by identifying a test as a measure of their spatial ability. Specifically, when women are told that a task will be used to measure their spatial ability, their performance is worse than when they are not told anything about the purpose of the task. Crawford et al. (1995) also contend that this difference in spatial ability due to social stereotypes is evident even during childhood. They propose that the gender-specific toys that are given to children engage different types of abilities from a very young age. For example, boys are often given blocks and LEGOS from which they are able to build models and structures from pictures and diagrams. In contrast, girls are often given dolls and Barbies which they are able to nurture but not manipulate. “Boy” toys seem to help engage and develop spatial abilities while “girl” toys do not. Thus, it seems natural to link men’s superior spatial ability to the lack of female experience and familiarity with spatial tasks. Although the mirror-tracing task will be a novel task for both males and females, if Crawford et al. are correct, the spatial nature of the task will favor the performance of males because of to their experience and familiarity with spatially orientated tasks.

Some researchers have proposed that the gender differences in spatial abilities can, in part, be attributed to performance and situational factors, like speed (Goldstein, Haldane, & Mitchell, 1990). Maccoby & Jacklin (1974) found that males tended to perform tasks quickly, whereas females tended to work more slowly and carefully. Accordingly, Goldstein et al. (1990) claimed that sex differences in spatial abilities can be eliminated when spatial tasks do not incorporate time limits into the task. Gender difference in completion time of spatial task was also noted by Prinzel and Freeman (1995) who measured the speed and accuracy on a mental rotation task of 40 male and 40 female students. Prinzel and Freeman (1995) reported that females had significantly longer reaction times when making a correct response than did males (d = -0.83). Thus, because the mirror-tracing task is similar in many regards to other spatial tasks, one could presume that the males will complete the mirror-tracing task more quickly than females.

Arguments against Gender Differences in Spatial Ability

While many researchers contend that substantial sex differences in spatial abilities exist, other researchers maintain that substantial gender differences in spatial abilities do not exist (Caplan et al., 1985). Researchers who challenge the notion of sex differences argue that the current research on sex differences in spatial ability is inconsistent and flawed. The most well-known paper supporting that evidence for sex differences is unreliable was written in 1985 by Caplan, MacPherson, & Tobin. Caplan et al. (1985) suggested that part of the reason for some of the inconsistency in research findings may be due to a lack of a clear and agreed upon definition for "spatial ability." Until a universal definition for the construct of spatial ability is developed, researchers will not be able to reach a consensus concerning the existence of sex differences in spatial abilities, according to the authors. Moreover, Caplan et al. (1985) claimed that experimental tests are often erroneously categorized as measures of spatial ability and are then used to describe inaccurate conclusions regarding gender differences in spatial ability, when the tests are not actual measures of spatial abilities. Caplan et al. (1985) also suggested that results drawn from many studies are often over-generalized. For example, single-test studies are used to draw overall conclusions regarding sex differences in spatial abilities.

While some researchers make claims about possible environmental causes for gender differences in spatial abilities, Lohman (1986) maintained that gender differences in spatial abilities can be attenuated with exposure and practice. Thus, he claimed that if female children or adults are given ample opportunity to practice a spatial task, gender difference will eventually dissipate with time. Therefore, according to Lohman (1986), females will be able to perform the mirror-tracing task as well as males with practice.

CHAPTER 3

PSYCHOMOTOR ABILITIES

Defining Psychomotor Ability

Although there is no general consensus on the definition for psychomotor abilities Ackerman (1988) defined psychomotor abilities in stating, “The psychomotor domain represents an amalgamation of a family of related but independently identifiable sub-abilities. A general psychomotor ability represents individual differences predominantly in the speed of responses to test items with little or no cognitive processing demands.” (pp. 290-291). Chaiken, Kyllonen, & Tirre (2000) explained the basic elements within a psychomotor task in stating, “A classic psychomotor task may be one that stresses *continuity* (involves the transition of a continuous perceptual display into a continuous motor response), *timing* (requires the performer to time a response or to estimate time accurately), and *coordination* (is done in conjunction with another task).” (p. 199)

Taxonomy of Psychomotor Abilities

Peterson and Bownas (1982) summarized the functional classification system that was developed by Theologus, Romashko, & Fleishman in 1973 for categorizing the important dimensions of psychomotor abilities. According to Peterson & Bownas (1982) the mirror-tracing task is one of the more complex psychomotor tasks and falls under the psychomotor subdivision of arm-hand steadiness. Carroll (1993) added aiming to the psychomotor subdivisions although it was not included in Peterson & Bownas’s (1982) classification system. According to Carroll (1993) the mirror-tracing task would also fall under the subdivision of aiming.

Peterson and Bownas (1982) define *arm-hand steadiness* as follows:

> This is the ability to make precise, steady arm-hand positioning movements, where both strength and speed are minimized. It includes steadiness during movement as well as minimization of tremor and drift while maintaining a static arm position. This ability does not extend to the adjustment of equipment controls (p.71).

The mirror-tracing task clearly meets the criterion of an arm-hand steadiness task because it requires participants to keep their arms and hands steady so that they will not trace outside of the track and receive an error.

The mirror-tracing task also falls under the category of aiming. Carroll (1993) describes aiming as, "the ability to carry out quickly and precisely a series of movements requiring eye-hand coordination" (p.536). Furthermore, Carroll (1993) noted that tracing tasks often require aiming. The mirror-tracing task definitely meets the criteria for aiming because the participant must implement hand-eye coordination to quickly and precisely complete the tracing task.

Gender Differences in Psychomotor Tasks

Gender differences in psychomotor tasks exist; however, males and females show superior psychomotor skills across different subdivisions of psychomotor tasks.

Male Superiority

Males show superior psychomotor skills when engaging in tasks that require targeting. According to Kimura (1999) one of the most reliable and largest sex differences in ability involves the motor activity of accurately aiming objects at a target, which is referred to as "targeting." Greater male performance in targeting tasks can be seen very early in life, before girls and boys differ in muscle bulk or strength, or have had much differential experience in targeting tasks (Kimura, 1999).

Males complete simple tasks faster than females (Ruffer, 1984). Fleishman (1972) described reaction time tasks as the speed with which the individual is able to respond to a stimulus when it appears. Ruffer (1984) documented this significant male superiority ($p < .001$) when he asked 1,183 elementary students to press a button with their thumb, as quickly as possible, when they heard a buzzer. According to Ruffer, these results are consistent with many other reaction time studies (e.g. Gilbert, 1894; Thomas, Gallagher, & Purvis, 1981; Garrett & Schneck, 1933).

Female Superiority

Females, in contrast, excel in psychomotor tasks that require fine motor skills. As indicated by Kimura (1999) women tend to be faster than men when completing a series of movements involving the fingers. Maccoby and Jacklin (1974) summarized past research to note that females' superior fine motor skills are especially evident when the psychomotor tasks are speeded or timed. However, it should be noted that men tend to be faster at performing a single movement, such as touching one target repeatedly with the same finger (Kimura, 1999). Therefore, it seems that men are quicker at completing single movement, while women are quicker at completing several, integrated movements. This female advantage in fine motor skills could be accounted for by better control over distal musculature or by better ability to coordinate several movements into a single task unit (Kimura, 1999).

Females also perform better than males when completing arm-hand steadiness tasks. Fleishman (1972) described arm-hand steadiness as the ability to make precise arm-hand positioning movements where strength and speed are minimized. This ability also extends to tasks that require participants to complete steady movements. Ruffer (1984) found evidence for this significant female advantage when he asked 1,183 elementary students to hold a stylus inside a hole without allowing the stylus to touch the sides of the hole. Ruffer (1984) found that males made more errors (touches) than females ($F = 29.47$, $p < .001$). According to Ruffer, these results are consistent with other experiments that tested arm-hand steadiness (e.g. Dewey, Child, & Ruml, 1920; Briggs & Tellegen, 1971).

Therefore, because the mirror-tracing task is a fine motor task that requires arm-hand steadiness, the literature proposed by Ruffer (1984), Fleishman (1972), and Kimura (1999) suggests that females have some advantages to males when completing the mirror-tracing task. However, this literature does not take into account the spatial demands of the task, which is not dominated by a female advantage.

CHAPTER 4

PRACTICE EFFECTS

According to Newell & Rosenbloom (1980) task practice on consistent tasks (such as the mirror-tracing task) will follow a power law that is defined by plotting the logarithm of the completion time against the logarithm of the number of trials. This law seems to always produce a straight line with a negative slope. Therefore, larger practice effects would be found for the difference from initial to intermediate practice than from intermediate to final assessment, assuming equal numbers of trials between the two intervals.

It is also important to note the effects of practice on mirror-tracing task performance for both males and females. In 1983, Blatter tested the effects of practice on spatial ability when he asked 48 participants to complete a spatial ability pre-test. Participants who were assigned to the experimental condition were then asked to practice spatial tasks, while the participants in the control condition were not. Finally, all participants completed a spatial ability post-test. Blatter reported that while both males and females who were assigned to the experimental group, showed improvement in their spatial ability test scores, the females showed significantly greater improvement than did the males (1983). Blatter (1983) reported an effect size of .54 for male improvement and .74 for female improvement. Likewise, Connor, Schackman, & Serbin (1978) conducted a similar study and also found that female performance improved significantly more from pre-test to post-test than did male performance.

Saccuzzo, Craig, Johnson, and Larson (1996) examined the effect of practice on computerized spatial tasks and noticed that although men generally did better than women upon initial assessment of spatial abilities; no significant difference was found after participants were encouraged to practice. Similarily, Kass & Ahlers (1998) reported non significant gender differences in a visual spatial task after participants practiced.

CHAPTER 5

PERSONALITY TRAITS AND TASK PERFORMANCE

Although no personality traits have been directly correlated with performance on the mirror-tracing task, studies have been conducted that have correlated personality traits with performance on other spatial and psychomotor tasks. Because the mirror-tracing task is both spatial and psychomotor in nature, it is important to note what personality traits have been associated with tasks that require these abilities.

Introversion

According to Eysenck (1967), introversion is a personality trait that describes a person who is serious, reserved, and less sociable. Interestingly, introversion has been shown to be positively correlated with both spatial and psychomotor abilities. In 1986, Gormly and Gormly conducted a study that asked 63 participants to complete a spatial reasoning test. These participants were all members of the same fraternity and were also asked to rate one another on social introversion. Gormly and Gormly (1986) reported a positive correlation between performance on the spatial reasoning task and social introversion ($r = 0.72$). Furthermore, Smith (1964) reported that "relatively high spatial or mechanical ability tends to be accompanied by introverted, schizothymic, desurgent or asocial traits" (p.237). Therefore, it seems that introversion should also be positively correlated with performance on the mirror-tracing task.

Anxiety

Previous research has shown that people who are anxious show a loss in both visual and motor coordination. Beier (1951) conducted a study where 62 participants were asked to complete a number of abstract reasoning tasks, including the mirror-tracing task. Participants who were placed in the experimental group were also administered the Rorschach Test for the purpose of inducing stress. According to Beier (1951) individuals who are faced with threat and who are in a state of anxiety show a significant loss in visual motor-coordination. Because the mirror-tracing task requires visual and motor coordination, it seems that anxiousness should be negatively correlated with performance on the mirror-tracing task.

CHAPTER 6

APPLIED RELEVANCE OF THE TASK

Because the mirror-tracing task is unique in the sense that it requires both spatial and psychomotor abilities, it is relevant to a variety of different occupational domains. For example, it is essential for dental students to learn how to make precise and subtle hand movements while using a mirror to see clients' teeth. Therefore, dental students must use spatial abilities in order to visualize the teeth through a mirror and psychomotor abilities to make meticulous finger and hand movements within the mouth. Many researchers have recognized the psychomotor nature of dental work and therefore have developed a variety of psychomotor training techniques to help increase dental students' performances (e.g. Feil, 1989; Feil, Reed, & Hart, 1986). Neumann (1988) noted that performance on mirror-tracing tasks could be used to help predict dental student success or to identify dental students who may need more training. Engineers are also likely to use spatial and psychomotor abilities. For example, engineers are often asked to fix problems or develop plans for complex machinery which requires being able to visualize objects from multiple perspectives and using fine motor skills to implement physical plans. In fact, Miller & Bertoline (1991) believed that spatial skills are such an important aspect of engineering that they suggested curriculum changes within engineering departments that would implement greater spatial training.

Clearly, success in many applied settings like dentistry and engineering requires the use of spatial and psychomotor skills. In order to promote success within these fields, it is important to understand the existence of any gender differences that occur when completing tasks that require such abilities. Because the mirror-tracing task requires spatial and psychomotor abilities, it allows researchers to test overall gender differences in performance of the task, as well as micro-level gender differences. Therefore, the use of this task will allow researchers to see at what point in the task gender differences occur.

CHAPTER 7

CURRENT RESEARCH

After thoroughly reviewing the literature that is summarized above, it is clear that while many studies have incorporated the mirror-tracing task into their research, no study has ever looked at the micro-level task completion gender differences. Furthermore, I have not been able to find any research that examined asymptotic performance for the task, which incorporates a sufficient number of practice trials so that performance improvements become negligible. Therefore, this research is unique in that gender differences in micro-level completion of the mirror-tracing task along with practice effects are investigated. Based on previous mirror-tracing task research and research concerning the abilities that are required to complete the task (spatial and psychomotor), I have made the following predictions:

Hypothesis 1: Over the course of 40 trials, practice will result in an improvement of speed (effect size = .70). (The effect of practice is expected to follow the power law of practice,such that intermediate amount of practice will yield an initial/20-trial effect size of .48) This hypothesis is based on the power law of practice which is summarized by Newell & Rosenbloom (1980). According to the power law, larger practice effects should be found for the difference from initial to intermediate than from intermediate to final assessment.

Hypothesis 2: Gender differences in completion time are expected to be largest at initial trial performance, and get smaller with practice. At initial trial performance, males are expected to perform faster than females (effect size = .65). By intermediate practice (20 trials), the effect size is expected to be .50, and at 40 trials, the effect size is expected to *be .45.* This hypothesis is based on the spatial literature that points out male superiority in timed tasks (Goldstein et al., 1990; Prinzel & Freeman, 1995) and the tendency for females to complete spatial tasks more slowly (Maccoby & Jacklin, 1974). It is also based on research that was conducted by Blatter (1983) which proposed that females benefit from practice more than males. However, this hypothesis is also influenced by Saccuzzo et al. (1996) and Kass & Ahlers (1998) who report that after practice there is no gender difference in spatial task performance.

Hypothesis 3: Females and males will make a similar number of errors (deviations outside of the tracing track) during initial, intermediate, and final assessments. This hypothesis is based on the gender differences in mirror-tracing task literature that reports no difference in number of errors made by females and males (Allen & Matthews, 1997; Alexander, Packard, & Peterson, 2002). This hypothesis is also derived from the fact that the mirror-tracing task contains both spatial and psychomotor aspect. Thus, the spatial nature of the task would seem to give a male advantage, while the psychomotor nature, that requires fine motor control movements, would seem to provide a female advantage. As a result, I suspect that males and females will utilize their various advantages and perform equivalently on the task, when number of errors are being measured.

Hypothesis 4: Number of errors made during initial assessment of the mirror-tracing task will be negatively correlated with introversion (anticipated r =-.20). This hypothesis is based on the literature that indicates a positive correlation between spatial and psychomotor abilities with introversion (Gormly & Gormly, 1986).

Hypothesis 5: Number of errors made during initial assessment of the mirror tracing task will be positively correlated with anxiety (anticipated r = .15). This hypothesis is shaped by the literature that showed a decrease in mirror-tracing task performance when participants were under stressful conditions (Beier, 1951).

The purpose of this research is to examine the gender differences that exist when male and female participants complete the mirror-tracing task. This task was chosen because it requires both spatial and psychomotor abilities and is unusual in the sense that it has a far higher correlation with standard spatial ability measures than do most other psychomotor tests. This research focuses on looking at the gender differences in speed, accuracy, and practice effects, while also investigating two personality traits that correlate with performance on the task: introversion and anxiety. However, before this research could begin, a calibration study was first conducted.

CHAPTER 8

CALIBRATION STUDY - OBTAINING SPEED-ACCURACY TRADEOFF FUNCTIONS

A calibration study was conducted in order to better understand the relationship between speed and accuracy for the mirror-tracing task. To achieve this, speed-accuracy tradeoff functions were developed. The purpose of speed-accuracy tradeoff functions is to represent the relationships between speed and accuracy for certain tasks (Salthouse & Hedden, 2002). One method for developing speed-accuracy tradeoff functions is to manipulate the instructions given to participants so that there is varying emphasis on speed or accuracy across different trials (Lohman, 1989).

Ten (5 male and 5 female) participants were recruited to participate in the calibration study. They were all asked to complete the mirror-tracing task described above. To reach asymptotic performance, participants completed a total of 240 practice trials. The practice trials were broken up into three, one-hour lab sessions, so that participants only completed 80 mirror-tracing trials per lab session. After each block of 40 trials, participants had a 5 minute break to stretch or use the restroom. During the first two sessions, participants were asked to simply practice the task. However, during the third session, for the final 40 trials, participants were instructed to complete the task as quickly as possible, without regard to error. They were then instructed to complete the task as carefully as possible without regard to completion time. These practice sessions gave the participants an opportunity to first get really efficient at the task and second to experience what it is like to respond to different instructions regarding task completion.

More specifically, they were given the opportunity to practice what it would be like to respond the speed only instruction condition and the accuracy only instruction condition.

Once asymptotic performance had been reached, through the three previous sessions, participants completed five more, one-hour lab sessions, where instructions were manipulated to emphasize speed, accuracy, or neither so that each lab session required participants to follow a different set of instructions. During each session, participants completed 40 trials, had a three minute break; completed 40 trials, had another three minute break; and then completed another 20 trials. Therefore, during these trials participants completed 100 trials per one hour lab session. Each participant was given five different instruction sets:

1. Speed Only: "For the next hour, we want you to do the task as fast as you can. This means that you should not worry about how many errors you make. Just try to get the whole figure traced with as much speed as possible. For example, if you complete the figure with no errors, you are probably not going as fast as you can. If that happens, try to go even faster on the next trials."

2. 80/20: "For the next hour, we want you to put the majority of your efforts toward completing the task as fast as you can, but you should pay some attention to reducing errors. Think of doing the task with 80 percent of your effort devoted to speed, but only 20 percent of your effort toward keeping the number of errors low. For example, if you make only one or two errors, you might try to increase your speed a little more on the next trials. If you find that you are making a lot of errors, try slowing down a little on the next trials."

3. 50/50: “For the next hour, we want you to divide your efforts equally toward completing the task as accurately and as quickly as you can. Think of doing the task with 50 percent of you effort devoted to speed, and 50 percent of your effort devoted to accuracy. For example, if you are making no errors, you need to try and increase your speed on the next trials. If you make numerous errors, you need to try and decrease your speed on the next trials.”
4. 20/80: “For the next hour, we want you to put the majority of your efforts toward completing the task as accurately as you can, but you should pay some attention to completing the task quickly. Think of doing the task with 80 percent of your effort devoted to keeping the number of errors low, but only 20 percent of your effort toward speed. For example, if you make two or three errors, you might try to decrease your speed a little more on the next trials. If you find that you are not making any errors, try increasing your speed a little on the next trials."
5. Accuracy Only: “For the next hour, we want you to do the task as accurately as you can. This means that you should not worry about how long it takes you to complete the task. Just try to get the whole figure traced with as few errors as possible. For example, if you are making even one or two errors, you are probably going too fast. If you find that you are making any errors, try slowing down on the next trials.”

The order of instruction sets and tracing figures were randomized to prevent any ordering or sequencing effects.

After conducting a one-way ANOVA for the calibration study portion of this thesis, it became clear that both speed and accuracy have statistically significant difference between genders. Therefore, males and females do not have the same speed-accuracy tradeoff functions. Males' speed-accuracy tradeoff functions were most represented by a cubic function with the following equation to best fit the model: $CT = 18.324 - 3.042(accuracy) + 0.612(accuracy)^2 - .034(accuracy)^3$. And females' speed-accuracy tradeoff functions were most represented by a linear function with the following equation to best fit the model: $CT = -.591 * (Accuracy) + 11.99$.

The purpose of conducting the calibration study was to provide more information about the relationship between speed and accuracy for males and females for this particular task, the mirror-tracing task. Now that I have the knowledge that males and females have two separate speed-accuracy trade-off functions, and have the above two equations, I am able to predict a participant's speed or accuracy as long as I know their gender.

CHAPTER 9

METHOD

Data were collected from three studies, all of which concerned psychomotor abilities and the mirror-tracing task, to test the hypotheses proposed within this paper: Experiment 2 of Ackerman & Cianciolo's (1999) study, Experiment 3 of Ackerman & Cianciolo's (2000) study, and Experiment 1 of Field's (1998) study. However, data related to personality traits was only collected from the Ackerman & Cianciolo (2000) study because it was the only study that measured personality traits.

Participants

One hundred and seventeen students from the University of Minnesota participated in Experiment 2 of Ackerman & Ciancicols's (1999) study for either credit in their introductory psychology course or for $30.00 cash. All participants were native English speakers, between 18 and 30 years old, and had normal or corrected-to-normal hearing, vision, and motor coordination. The final sample consisted of 36 male and 81 female participants (*M* age = 18.8 years old, *SD* age = .72, range =18-21 years old) (Ackerman & Cianciolo, 1999).

Ninety-eight adult participants participated in Experiment 3 of Ackerman & Cianciolo's (2000) study. All participants were native English speakers and had normal or corrected-to-normal hearing, vision, and motor coordination. The final sample consisted of 45 male and 53 female participants (*M* age = 20.8 years old, *SD* age = 2.32, range = 18-28 years old) (Ackerman & Cianciolo, 2000).

One hundred and thirty-seven participants participated in Experiment 1 of Field's (1998) study. The sample consisted of 46 male and 91 female participants (*M* age =21.6 years old, *SD* = 3.24 years old) (Field, 1998).

Apparatus

A computerized version of the mirror-tracing task was used. Instead of using an actual mirror, this version had participants trace on the left side of the monitor screen (which was blank), with the results of the tracing shown on the right side of the screen (Ackerman & Cianciolo, 1999). Participants used either a TouchPen stylus or their finger to trace the designs. When the participants were tracing inside the track, a white tracing line appeared; however, when the participants accidentally traced outside of the track, a purple tracing line appeared. An error tone also indicated that participants had traced outside of the designated path. Tracing patterns were developed using the same number of corners as the original mirror-tracing star (Snoddy, 1920). The participants' output was reflected across both the *x* and *y* axes. As a result, as the participant moved the stylus (or their finger) up on the left side of the screen, the path traced moved down, and as the participant traced left, the path traced moved right (Ackerman & Cianciolo, 1999). Total completion time and total errors were displayed after each tracing trial.

Measures

Introversion measure

Introversion was assessed using some of the personality scales from Tellegen's Multidimensional Personality Questionnaire (MPQ; Tellegen, 1985). Church (1994) describes Tellegen's four-factor model which proposed four personality dimensions: Agentic Positive Emotionality (PEM-A), Communal Positive Emotionality (PEM-C), Negative Emotionality (NEM) and Constraint. Of particular relevance to introversion are the Social Potency and Achievement scales which, according to Church (1994), are associated with the Agentic Positive Emotionality dimension. Church (1994) described PEM-A as “a generalized social and work effectance dimension…which appears to combine elements of Big Five Extroversion and Conscientiousness” (pp.899). Therefore, it would seem that participants who score low on Social Potency and higher Achievement are likely to be considered introverts.

Anxiety measure

Anxiety was assessed using some of the subscales from the Motivational Trait Questionnaire (MTQ; Heggestad & Kanfer, 2000). Of particular relevance to anxiety are the Worry and Emotionality subscales. The items on the Worry scale focus on aspects related to evaluation apprehension in performance contexts, while the items on the Emotionality scale focus on emotions which are related to performance in evaluation contexts (Kanfer & Ackerman, 2000).

Procedure

The mirror-tracing portion of these studies took place over two sessions. During the sessions, participants were seated in front of computers with 15 inch touch-panel monitors. The mirror-tracing trials began with a variable 500 to 1,000 msc hold on a home key, followed by an auditory “ready, set, go” signal.

In Experiment 2 of Ackerman & Cianciolo’s (1999) research, the participants completed the mirror-tracing task using both the TouchPen stylus and their fingers. They completed 4 sets of 5 trials using the TouchPen in one session and then completed another 4 sets of 5 trials using their fingers in a different session. Each set of tests consisted of a different stimulus/tracing pattern.

In Experiment 3 of Ackerman & Cianciolo's (2000) study, participants only used the TouchPen stylus to trace the task and participated in two sessions. In the first session, the participants initially completed 3 sets of 10 trials. During the second session, the participants were given a single stimulus, and did 4 blocks of 10 trials.

In Experiment 1 of Field's (1998) study, participants took part in two sessions, both of which required the participants to complete 2 sets of 10 trials.

CHAPTER 10

RESULTS

To assess, my first hypothesis, I conducted a one-way repeated measures analysis assessing completion time for the mirror-tracing task over the course of 40 trials. An α level of .05 was adopted for all analyses. The results found support for Hypothesis 1, showing substantial improvement of task speed with practice. This great improvement in mirror-tracing speed for both males and females is evident both by the effect sizes the results produced (d=3.02 from initial to final assessment and d=1.61 initial to intermediate assessment) and in the below graph.

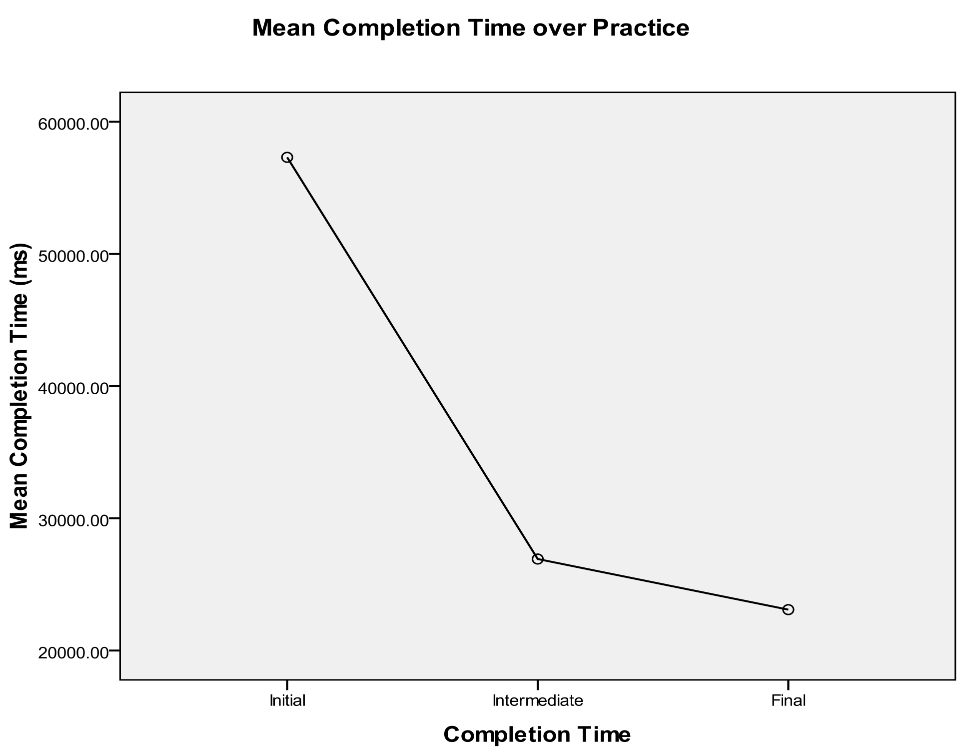

Figure 2. Completion time, in milliseconds, of mirror tracing task at initial, intermediate, and final assessment.

The x-axis is separated by initial, intermediate, and final assessment. Performance for initial assessment was measured at the first trial, performance for intermediate assessment was measured at the twentieth trial, and for final assessment performance was measured at the fortieth trial. On the y-axis completion time, or speed, of the task is measured in milliseconds. Therefore this graph clearly shows that completion time decreases substantially.

To assess my second hypothesis, I conducted a one-way repeated measures analysis with gender as a between subjects factor. I assessed completion time of the mirror-tracing task at initial, intermediate, and final assessment, for both males and females. Results supported my hypothesis that males would be faster than females during all three assessment periods. The results showed the following effect sizes for each assessment period: d=.93 at initial assessment, d=.50 at intermediate assessment, d=.64 at final assessment. The initial and intermediate effect sizes were very close to the effect sizes that were anticipated by my hypotheses; however, the final effect size increased instead of decreased as expected. Therefore, the gender difference only decreased from initial to intermediate, not from intermediate to final.

The third hypothesis was also evaluated using a one-way repeated measure analysis with gender as a between subjects factor. For this hypothesis, the repeated measure was the total number of errors made during the mirror-tracing task during initial, intermediate, and final assessment, and again the between subjects factor was gender. The results did not support my hypothesis that males and females would make a similar number of errors during initial, intermediate, and final assessment of the mirror-tracing task. Instead, I found that females made significantly more errors than males during initial assessment (*F=0.326, p< .0166)* but they did make a similar number of errors as males during intermediate and final assessment *(F=2.078, F=1.899, ns)*. The graph below helps to illustrate these findings:

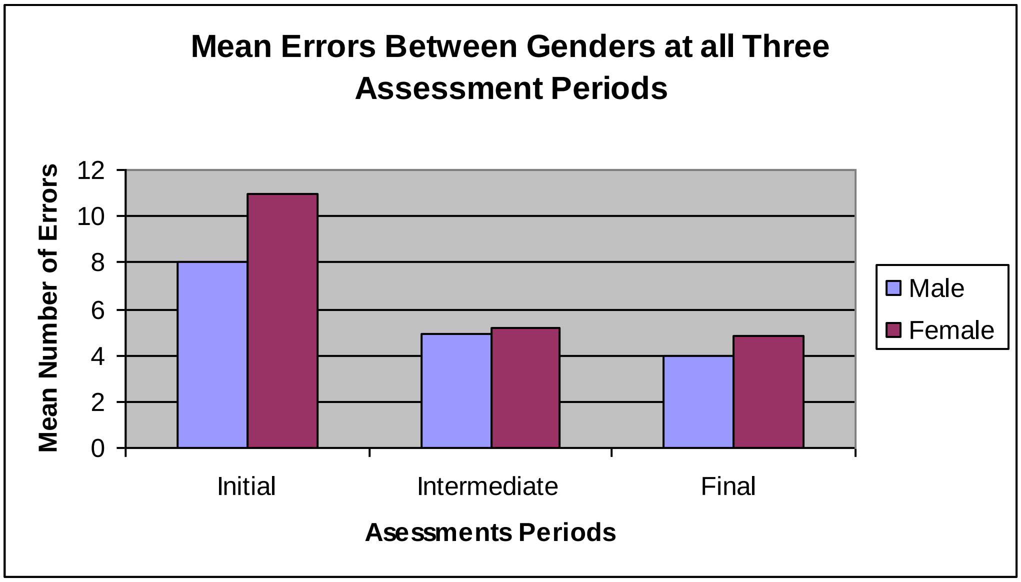

Figure 3. Number of errors for males and females while completing the mirror-tracing task at initial, intermediate, and final assessment.

From this graph it is clear that females make more errors than males. However, a post-hoc test was required to see which assessment periods were significantly different for number or errors made between males and females. After conducting independent T-tests, with an α level of .0166, I found that the only statistically significant gender differences in the number of errors made were found at initial assessment (*F=.326,p<.0166)*. There were a similar number of errors made by males and females at intermediate and final assessment.

For the fourth and fifth hypothesis, two Pearson correlations were conducted between the number of errors made and anxiety and introversion. No overall significant correlations were found (*r=.133* between initial errors and anxiety*; r=.098* between initial errors and introversion; $r = -.185$ between initial errors for male participants and anxiety; $r = .342$ between initial errors for male participants and introversion; $r = .132$ between initial errors for female participants and anxiety; $r = .063$ between initial errors for female participants and introversion. Therefore, I failed to confirm either of my hypotheses that were concerned with personality traits.

Finally, the thesis contained both a calibration study and an archival study so that a combined performance measure for the mirror-tracing task could be developed. To do this, the data from the archival study was integrated into the calibration regression equations and the results showed that the archival portion of the study support the calibration portion of the study in that the two equations/functions are statistically different ($p < .000$). An effect side of $d = .644$ was also found for the difference between men and women for this combined performance measure of the mirror-tracing task.

CHAPTER 11

DISCUSSION

This study examined the micro-level gender differences in mirror-tracing task performance. Specifically, it focused on looking at the differences in completion time, total numbers of errors within a trial, practice effects, and the correlations between two personality traits and performance on the task. The results showed significant improvement in task completion time for both males and females over 40 trials. They also showed that males completed the mirror-tracing task faster than females throughout all three assessment periods. However, the results showed females making more errors than males only during initial assessment, not during intermediate or final assessment.

The fact that all participants, males and females, showed significant improvements in completion times across 40 trials indicates that practice on the mirror-tracing task followed the power law, which was described by Newell & Rosenbloom (1980) and generally produces a straight line with a negative slope when graphed.

The results of this research found that with practice males and females can both reach high levels of performance in the mirror-tracing task. First, the results are supported by the research of Saccuzzo, Craig, Johnson, & Larson (1996) who reported that gender differences in spatial abilities can be eliminated when females are encouraged to practice. In this study, at initial assessment females made significantly more errors than males; however, with practice, at intermediate and final assessment there were no significant differences in the number of errors made by males and females. This implies that after practicing a task, female participants will make a similar number of errors on a task,compared to males. However, the results of this research are also consistent with Maccoby & Jacklin (1974) who stated that females have a tendency to complete spatial tasks more slowly than males. In this study, males completed the mirror-tracing task faster than females at three assessment periods, though it is important to note than females' completion time did improve more with practice. So, perhaps this research suggests that gender differences in spatial or psychomotor task can be attenuated when females are allowed to practice the task, as long as speed is not a criterion in task evaluation.

Implications

The mirror-tracing task was chosen because it requires both spatial and psychomotor abilities and is unusual in the sense that it has a far higher correlation with standard spatial ability measures than do most other psychomotor tests. Because the mirror-tracing task incorporates both spatial and psychomotor abilities, it provides researchers with an example of how more real-world tasks (that feature more than one ability) exhibit distinctive gender differences. Many of the STEM (science, technology, engineering, and mathematic) fields require the use of both spatial and psychomotor abilities. For example, a student majoring in engineering will rely on his or her spatial abilities to mentally visualize the solution to a complex problem and then will also rely on their psychomotor abilities when they need to physically fix the problem. Dentistry is another applied setting that requires the use of both spatial and psychomotor abilities. Dental students use spatial abilities to allow them to look into a mirrored image of a tooth and then make appropriate finger and hand movements, based on their psychomotor abilities.

The results of this research might have implications involving the ability to predict success in occupations and academia. As stated above, success in the STEM and dentistry fields often requires students or employees to integrate a wide variety of abilities, especially spatial, psychomotor, perceptual speed, and mathematical abilities. Therefore, this research will begin to help us understand gender differences within some of these abilities. Furthermore, teachers and employers should now be able to use this information to better understand and predict the success and struggles of their employees/students. The strongest implication this study could make is for school systems and parents to realize that gender differences do exist and to encourage training and exposure to a variety of activities in the hopes of decreasing differences. Hopefully, this study will encourage future researchers to use this knowledge of gender differences in the mirror-tracing task to predict and one-day attenuate sex differences through strategies for increasing performance on tasks that incorporate both spatial and psychomotor abilities.

Finally, another important implication of this study is to encourage other researchers to look further into the causes of gender differences. All too often, researchers point out the existence of gender differences within a task or ability, but fail to understand the micro-level differences that contribute to the overall gender difference. Hopefully, this research will encourage other investigators to look at the gender differences among the variables that make-up the task.

Limitations

Possible limitations of this study could have occurred due to the fact that I am using data from three separate studies to investigate the research questions. Because each study administered different numbers of stimulus sets and trials, the participants could have experienced different practice effects. For example, participants completed different numbers of trials and therefore would have different levels of experience with the task. Participants who completed more trials within their experiment might have a better final performance score than a participant who completed fewer trials due to the amount of practice they were able to complete within the initial and final task performance measures.

Another important limitation could have occured through the differential use of fingers and TouchPens throughout the three experiments. This difference in procedure could cause participants to experience different levels of task difficulty and could also cause differing practice effects. Ackerman & Cianciolo (1999) noted the different practice effects when using a finger or the TouchPen stylus. According to their results, the TouchPen version exhibited a practice effect from initial block performance to final block performance with an effect size of $d = 0.69$; the finger version also exhibited a practice effect from initial to final block performance with an effect size of $d = 1.48$ (Ackerman & Cianciolo, 1999). Consequently, the use of differing tracing devices, within the three studies, could have similar conflicting practice effects within the current research project.

The calibration study within this research is also likely to be subject to a few limitations. First, due to a requirement set forth by the Georgia Institute of Technology IRB, subjects who participated in this study knew that we were studying gender differences. Therefore, it is possible that subjects may experience stereotyping effects while participating. Second, the mirror-tracing task program requires that participants trace the entire path. Consequently, when participants make mistakes they are required to go back and trace the area of the pattern that they skipped. This program requirement will affect the speed at which participants are able to trace the figure. For example, in the speed only instruction set, participants will not be able to concentrate only on speed because the program will require that they go back and fix mistakes, which in turn will alter their completion times.

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